BTEC Assignment Brief

Qualification	Pearson BTEC International Level 3 Foundation Diploma in Applied Science Pearson BTEC International Level 3 Diploma in Applied Science Pearson BTEC International Level 3 Diploma in Biomedical Science Pearson BTEC International Level 3 Diploma in Environmental Science Pearson BTEC International Level 3 Extended Diploma in Applied Science Pearson BTEC International Level 3 Extended Diploma in Biomedical Science Pearson BTEC International Level 3 Extended Diploma in Environmental Science
Unit number and title	**Unit 20: Applications of Physical Chemistry**
Learning aim(s)	**C:** Investigate chemical equilibrium in order to understand the extent to which reactions go to completion
Assignment title	**Chemical equilibrium**
Assessor	
Issue date	
Hand in deadline	

Vocational Scenario or Context	You are a newly appointed chemical engineering technician working for a chemical company that specializes in making a range of chemical products. In your role you need to have a good understanding of chemical equilibria. When planning to carry out a new chemical reaction in the laboratory or on a manufacturing plant it is essential to research and gain knowledge about the type of reaction to be carried out. This includes understanding equilibrium reactions where the reaction conditions and rate of forward and backward reaction needs to be considered. Changing the concentration, pressure, temperature and catalysis can have an effect on the position of equilibrium. This understanding will enable you to plan/design the equipment/apparatus or chemical plant, the materials used and estimate the reaction conditions which need to be used to carry out the reaction safely. In your first month in your job your supervisor has set up an induction programme for you. You will need to successfully complete this induction to be able to continue as an employee of the company.

Task	As part of your induction into your new role of chemical engineering technician you are required to **explain** the features of an equilibrium reaction and the effect of changing conditions; **determine** the equilibrium constant for reactions using different experimental methods; **carry out** calculations involving Kp and partial pressures of gases; **perform** complex calculations involving Kc, Kp, total pressure and mole fractions; **calculate** and **interpret** values of Gibbs energy, equilibrium constant and temperature; **analyse** the relationship between equilibrium constant, temperature, enthalpy and entropy for a range of

	reactions. Your final portfolio will contain the following 5 sections: Section 1 - Understand equilibrium reactions • **Explain** equilibrium reactions to show you understand that concentrations of reactants and products remain constant once equilibrium has been reached, the reactions continue and the rates of forward and backward are equal. Include sketches of concentration / time graphs to illustrate different systems that are in equilibrium. • **Explain** the effects of changing the concentration, pressure, temperature and catalysis on the position of equilibrium for the following three reactions. Write an expression for K_c to include units for the three reactions and show what will happen to K_c when pressure, concentration or temperature is changed for the reaction: o Reaction 1 – lime production from limestone (in a closed system) o Reaction 2 - the Contact Process o Reaction 3 - Esterification of alcohols Note these reactions were chosen to have different numbers of molecules on both sides, a range of different states of matter and different signs for enthalpy change for the forwards reaction. Section 2 – **Determine** the equilibrium constant for reactions using different experimental methods. • Methods of determining Kc experimentally: o titration (samples extracted from the reaction, quenched and titrated) o colorimetry (where reaction changes colour over time), change in time. Section 3 – Equilibrium Calculations worksheet A • Under supervision in lesson, complete 'Equilibrium Calculations worksheet A'. This will allow you to: o **Calculate** Kp given values of partial pressure or the total pressure and mole fractions at equilibrium, and vice versa. o **Calculate** of Kp given initial partial pressures of reactants (or mole fractions and total pressure) and equilibrium moles or partial pressure of products (or mole fractions and total pressure), or vice versa. o **Carry out** a range of complex calculations involving Kc, Kp and total pressure and molar quantities. The problems will involve more than one step and include: calculation of the equilibrium constant given only initial mole quantities for reactants and the percentage conversion or amount of products at equilibrium; calculation of the total pressure of the equilibrium system, given only molar quantities and Kp; determination of the number of moles at equilibrium or

initially for a reactant from Kp or Kc.

Section 4 - **Calculate** and interpret values of Gibbs energy, equilibrium constant and temperature

For each of the equilibrium reactions **A, B** and **C**, you will need to:

- Under supervision in lesson, **determine** the expression for the equilibrium constant K_c and **calculate** its value at the temperature given, providing correct units and appropriate significant figures.

Equilibrium A (the synthesis of methanol):

$$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$$

Substance	Concentration (at equilibrium)/ mol dm^{-3} (at 523K)
$CO_{(g)}$	3.75×10^{-3}
$H_{2(g)}$	4.35×10^{-3}
$CH_3OH_{(g)}$	4.25×10^{-3}

$$\Delta H^{\ominus}_r = -91 \text{ kJ mol}^{-1}$$

Equilibrium B (the Contact Process):

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

Substance	Concentration (at equilibrium)/ mol dm^{-3} (at 500K)
$SO_{2(g)}$	1.90×10^{-5}
$O_{2(g)}$	1.53×10^{-5}
$SO_{3(g)}$	7.50×10^{-2}

$$\Delta H^{\ominus}_r = -196 \text{ kJ mol}^{-1}$$

Equilibrium C (the decomposition of hydrogen iodide):

$$2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$$

Substance	Concentration (at equilibrium)/ mol dm^{-3} (at 764K)
$HI_{(g)}$	17.80
$H_{2(g)}$	1.920

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$I_{2(g)}$	3.634

$$\Delta H^{\ominus}_r = +10.4 \text{ kJ mol}^{-1}$$

The table below shows the ***K*** *the equilibrium constant* at standard temperature for each of the three equilibria:

Equilibrium	K (at 298k)
A	**2.75×10^{4}**
B	**3.48×10^{24}**
C	**1.14×10^{-3}**

- Under supervision in lesson**, determine** a value for **$\Delta G^{\ominus}$/kJ mol^{-1}** from the value of ***K*** provided, at the standard temperature of **298K**, using the equation (you must show your workings):

$$\Delta G^{\ominus} = -RT\ln(K) \qquad (\text{or } K = e^{\text{¿}})$$

where:

K *is the equilibrium constant;* **$\Delta G^{\ominus}$** *is the standard change of Gibbs energy;* ***T*** *is the absolute temperature (in Kelvins); and* ***R*** *is the gas constant (8.314 J mol^{-1} K^{-1})*

- **Interpret** this value of ***K*** by commenting upon the relative amounts of reactants and products that must be present and how complete the reaction is.
- **Interpret** what the sign and value of the standard change in Gibbs energy indicates for each equilibrium.

<u>Section 5 - Relationship between equilibrium constant and temperature, enthalpy and entropy worksheet B</u>

- Under supervision in lesson, complete 'Relationship between equilibrium constant and temperature, enthalpy and entropy worksheet'. This will allow you to:
    - **Analyse** the relationship between equilibrium constant and temperature, enthalpy and entropy for a range of reactions. Use a variety of equations in order to explore the links for ^G° = -RTln(K), ^G = ^H° – T^S° and the calculation of ^H° and ^S° for reactions from enthalpy and entropy data for the substances involved. There will be at least five problems to enable you to calculate each of the terms when you are provided with values for the other three. Use graphical means to analyse the effect of temperature on a given equilibrium reaction. From this determine the enthalpy change and entropy change from the gradient and the intercept. Show all your workings.

Checklist of evidence required	A portfolio that includes: • An explanation of the features of equilibrium and the effects of changing reaction conditions

	• A determination of the equilibrium constant experimentally using different methods • Calculations involving K_p and partial pressures of gases and complex calculations involving K_c, K_p, total pressure and mole fractions. Worksheet A • Calculations and interpretations of values of Gibbs energy, equilibrium constant and temperature • An analysis of the relationship between equilibrium constant, temperature, entropy and enthalpy for reactions. Worksheet B

Criteria covered by this task:	
Unit/ Criteria reference	To achieve the criteria, you must show that you are able to:
C.D3	Analyse the relationship between equilibrium constant, temperature, enthalpy and entropy for a range of reactions.
C.M6	Calculate and interpret values of Gibbs energy, equilibrium constant and temperature.
C.M5	Perform complex calculations involving Kc, Kp, total pressure and mole fractions.
C.P8	Carry out calculations involving Kp and partial pressures of gases.
C.P7	Determine the equilibrium constant for reactions using different experimental methods.
C.P6	Explain the features of an equilibrium reaction and the effect of changing conditions.
Sources of information to support you with this Assignment	All sources of information suggested are UK based. Centres are free to amend these sources to those available in the Country of delivery where more appropriate. www.edu.rsc.org.uk – Thermodynamic equilibria; Equilibrium starters 1 and 2 (16-18); Thermodynamics and equilibria of the Solvay Process; Le Chatlelier's Principle - various www.STEM.org.uk - Chemical equilibrium an introduction; Equilibria: Delivery guide for AS and A level chemistry; Nuffield Physical Science section 6.

	Within the copyright laws learners could search YouTube for:– Reactions in Equilibrium, Introducing chemical equilibrium; Le Chatelier's Principle; What is chemical equilibrium
Other assessment materials attached to this Assignment Brief	Centres must create and internally verify their own versions of the following worksheets referred to in the Task: 1. 'Equilibrium Calculations worksheet A' **2.** 'Relationship between equilibrium constant and temperature, enthalpy and entropy worksheet'
Notes to the Assessor and technician	The practical activities suggested for this assignment are required to be safety checked by the Centre before use. Pearson Education can take no responsibility for the safety of any practical activities. Before doing any practical activity, you should always carry out your own risk assessment and refer to the necessary regulations. In particular, any local rules issued by your employer must be obeyed, regardless of what is suggested here. Centre should use Health and Safety information provided by a reputable source. In the UK such an example organization is CLEAPSS http://science.cleapss.org.uk/